OHIO ACADEMY OF SCIENCE 1990
GEOLOGY FIELD TRIP THROUGH GLEN HELEN
By Ben Richard and Mike Evers
(Afternoon Trip)

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INTRODUCTION

Glen Helen is land donated to Antioch College by a past president in memory of his daughter. Care is taken to maintain it as a natural laboratory. Our trip will be totally in this Glen. Please follow the rules listed in figure 1, especially, do not pick flowers and do not collect samples. Our entire tour will be on trails; therefore, there will be little need to leave them. The Glen is used by high schools and colleges as a natural laboratory and provides excellent samples of:

a) Silurian stratigraphy,
b) Glacial deposits,
c) Melt water erosion,
d) Mass wasting and stream transport,
e) Fracture control of erosion,
f) Travertine deposition and
g) Recent sediment deposition in a lake.

This trip will show examples of all these features.

A number of references describe the geology of the area in general. These are listed as selected references. At present, one of the Wright State University hydrogeology students, Mike Evers, is studying the "Yellow" spring and, recently, a geology student, Kirk Warren, completed a fracture study that included the Glen. This study has been highlighted in the morning trip through John ~~Byron~~ Bryan State Park and Clifton Gorge.

Glen Helen is a nature preserve of 1000 acres. All wildlife, vegetation and rock formations are protected. To provide that protection, visitors must observe the following rules:

- Remain on the trails at all times.
- Trails are for pedestrian use only. Wheelchairs are the only wheeled vehicles permitted.
- Horseback riding is not permitted except by persons affiliated with The Riding Centre and on land leased to the Riding Centre Association.
- Alcoholic beverages, intoxicating and hallucinogenic substances are prohibited.
- Please use the trash containers located at Trailside Museum, the Glen Helen Building and the Yellow Spring parking lot.
- Dogs and cats must be on leash (no longer than 6') at all times.
- Do not bring radios, phonographs, tape recorders or electrically amplified instruments into Glen Helen.
- No picnicking or camping is permitted in the Glen. Public picnicking and camping facilities are available at nearby John Bryan State Park.
- Fires are strictly prohibited. Smoking may be banned during periods of high fire hazard. In this event, warning flags or signs will be posted.
- Rock climbing, rappelling and other mountaineering activities are not permitted in the Glen.
- None of the many springs located in the Glen are approved as safe sources of drinking water.
- Boating and canoeing are permitted on the Little Miami River. Most of the year, the river is difficult to canoe through Glen Helen. The Jacoby Road Access Site, operated by the Greene County Recreation and Parks Department, is located on the southeast side of the river and is reached from Clifton Road.
- Wading and swimming are not permitted.
- Hunting and trapping are prohibited.
- Fishing is permitted south of Grinnell Road in the Yellow Springs Creek and in the Little Miami River.
- For reasons of safety and maintenance, no more than 6 persons are permitted on the swinging bridge at one time. Jumping on the bridge is prohibited.
- Please leave all monuments, markers and statues intact and in place.
- Some buildings located on Glen Helen land are residences. Please respect the privacy of their occupants.
- No birds or mammals, wild or domestic, are to be released in Glen Helen.
- Gathering and removal of wood for any purpose is prohibited.
- Permission to enter the portions of Glen Helen used by the Outdoor Education Center must first be obtained from the director of the Center. This includes land east of the Yellow Spring driveway, north and east of the Old Stage Coach Road (now the OEC driveway and fire lane) and north of the School Forest.
- Glen Helen is open to the public during daylight hours. Parking lots on Corry Street, near the Yellow Spring and Grinnell Mill may be closed and locked after dark. Vehicles are not normally locked in, but should they be, arrangements for their release may be made by contacting Antioch College Security. The Security office is located on the ground level of North Hall on the Antioch campus.
- TRAILSIDE MUSEUM is open Tuesday through Friday from 10:00-12:00 and 1:00 to 5:30 p.m.; Saturday and Sunday 12:00-5:30 p.m.
- THE GLEN HELEN BUILDING is open weekdays from 8:30 a.m. to noon and 1:00 to 4:30 p.m. and during evening and weekend hours when programs are scheduled.

GLEN HELEN IS A PRIVATE PRESERVE OWNED AND MANAGED BY ANTIOCH UNIVERSITY. VIOLATION OF THESE RULES MAY RESULT IN AN ORDER TO LEAVE THE GLEN.

Glen Helen Association
Antioch College
405 Corry Street
Yellow Springs, OH 45387
(513) 767-7375

Take A Hike

This Brochure Published on Behalf of Antioch University by Glen Helen Association.

figure 1

BRIEF DESCRIPTION OF THE GEOLOGY

Bedrock Geology

The entire Silurian rock section is exposed in Glen Helen. The part of the Glen we will be in today is the section from the Osgood Shale through the Cedarville Dolomite. The section here is essentially the same as that at John Byron State park. This was described by the Wittenburg University Group in their Intercollegiate Geology Field Trip of 1966. This section is included for your information (figure 2). The description of the units that follows comes from the G.S.A. guide by Ausich of 1987.

Dayton Formation - approximately 3.8 meters thick, even bedded. Fossils are not common in the Dayton Formation.

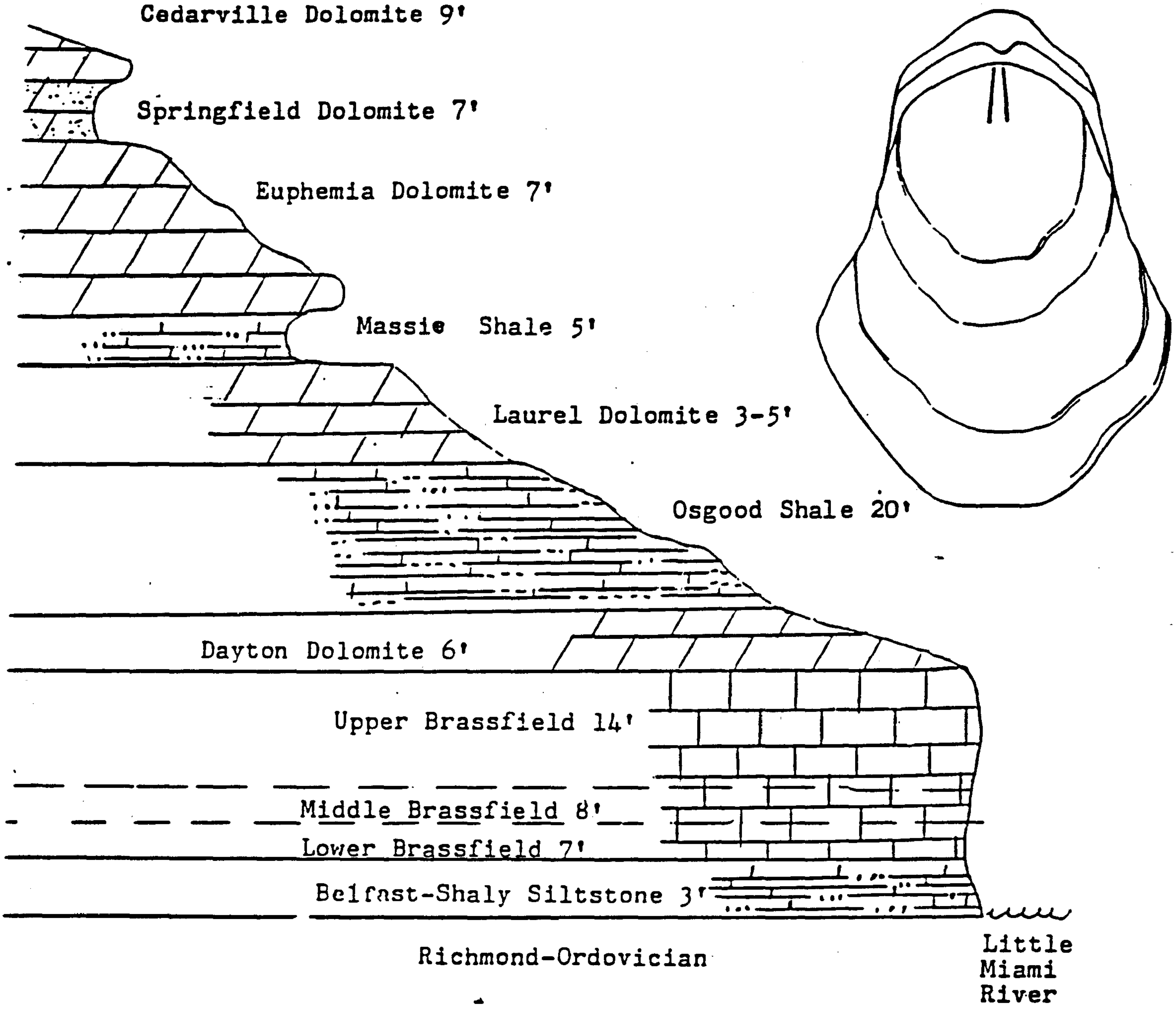
Osgood Shale - thickness varies from 6.2 to 8.1 meters. The formation contains burrows as well as body fossils of grapholites, crinoids, corals, bryozoans, and trilobites in low abundance.

Laurel Dolomite - thickness is approximately 0.9 meters with an average bedding thickness of 10 centimeters. Fossils found in the dolomite include crinoids, brachiopods, and corals.

Massie Shale - thickness is approximately 1.7 meters. This formation weathers easily to form caves with the much more resistant Euphemia Dolomite as the ceiling layer. Fossils are rare but crinoids, bryozoans, and brachiopods can be found.

Pentamerus laevis (P. oblongus in older publications) is the largest of our Silurian brachiopods (fig. 105), up to 5 inches long, and adult specimens are unmistakable. The width is always much less than the height, a feature which helps separate the genus from Gypidula. P. laevis is common in the Niagaran.

From Rocque and Marple, 1985.



Profile of John Bryan State Park

figure 2

Euphemia Dolomite - varies in thickness from 1.2 meters to 2.6 meters. At the base of the Euphemia the average bedding thickness is 10 centimeters. The remainder of the formation is a massive vuggy dolomite. The fossils present indicate a marine environment. At the contact with the above Springfield Dolomite there is a zone of Pentamerus brachiopods (see figure 2).

Springfield Dolomite - approximately 2 meters is exposed in Glen Helen by the Cascades. Characteristically it is even bedded with beds averaging 10 centimeters in thickness. The brachiopod Pentamerus is present in the formation.

Cedarville Dolomite - approximately 3.1 meters of the base of the formation is exposed by the Cascades in Glen Helen. The total thickness in Ohio is estimated to be as much as 30 meters. As in the Euphemia Dolomite vuggy-weathering can be seen as well as another discontinuous zone of Pentamerus near the base of the Cedarville - 1 meter above the Springfield Dolomite contact. Fossils that can be found in the formation are molds of brachiopods, cystoids, crinoids, and corals.

Erosion Prior to Glaciation

This area has probably experienced erosion since the end of the Paleozoic Era. During that time all rocks above those of Silurian age were removed by erosion. Sometime during this erosional period the Ancestral Kentucky and Hamilton river systems developed. There is no evidence of these ancestral valleys at this site but there is ample evidence of their presence in southwestern Ohio. There is much discussion about the relationship of these streams. I believe from what I have heard and my own observations that the Kentucky River is much older than the Hamilton and that it flowed north through this area. When it began no one has determined. The Hamilton began either shortly before or during the earliest glaciation and flowed south. Valley width and depth point toward a southerly flow. It is also interesting to note that the flow direction parallels the trend of the Cincinnati Arch. I believe as Gray (1973) that the Teays that is just north of here is an ice marginal stream and much younger than the Hamilton.

<u>Inter and Intraglacial Erosion</u>

The Teays River System which is several miles to the north of us is believed to be an ice marginal stream formed in this part of Ohio during either Kansan or Nebraskan glaciation. Evidence for this is:

a) the valley is incised into the bedrock,

b) the valley has few tributary valleys,

c) the altitude at the bottom of the valley is compatible with a lowered sea level caused by glaciation,

d) the sediments in the bottom of the valley (the Minford Silt) are magnetically reversed and thus deposited in either Kansan or Nebraskan time and

e) the drainage path of the Teays is rectilinear like the Ohio River.

This evidence points toward a stream that was formed quickly and then preserved by burial.

After the path of the Teays River Valley was established, a glacial ice dam formed in western Ohio, probably in Mercer County, to produce a large lake (Lake Teit). This lake overflowed the drainage divides between the Teays and the Hamilton and rapidly eroded gorges in these divides to produce the deep stage erosion that in part parallels the Hamilton drainage. The gorge of the Mad River several miles north of here is one of these overflow sites. One of our students (Don Bradley) has just finished a geophysical study of the gorge and has found there to be close to 200 feet of fill in it. This, along with drilling and seismic refraction studies north of the gorge by the Springfield water company, tells us the gorge was cut rapidly.

None of these erosional episodes are shown in this part of the Glen.

<u>Glacial Erosion</u>

Both stream valleys we will walk along were carved by outwash as was Little Miami River Valley where you saw it this morning. Evidence of the carving by outwash is the size of some of the erosional features and the narrowness of the valleys. There are remnant pot holes, plunge pools, and waterfalls much too large for the current streams to have produced them. Also note the linear nature of the streams. Their paths are joint controlled.

<u>Glacial Deposition</u>

In Glen Helen ground moraine covers the bedrock. In addition to the ground moraine, glacial erratics are present. Most of the ones we will see are igneous and metamorphic rocks from the Canadian Shield. Several of these exist along the trail and will be noted on the guided tour.

<u>Mass Wasting</u>

The Glen has numerous examples of mass wasting. Some of these are:

a) Creep - the trees especially show this in that their roots are uphill from their trunks and some trees are tilted down hill.

b) Back wasting of cliffs - the plunge pools at the water falls under cut the more massive units above until these massive units break off. The Springfield Dolomite weathers more rapidly than the Cedarville and Euphemia. When the back wasting of the Springfield is great enough, large blocks of the Cedarville break off.

c) Frost heaving - the large blocks of Cedarville are in transit to the stream. These are being moved by the action of creep and frost heaving.

Post Glacial Deposition

There are two prime examples of post glacial deposition which are:

a) travertine deposition by springs - the largest one here is at the "Yellow" spring and

b) man made deposition - a dam was built on Yellow Spring creek in the mid 19th century and began silting in the beginning of the 20th century.

TRIP LOG

Start at the Glen Helen Visitors center on Corry Street in Yellow Springs (see Figure 3). Proceed to the large erratic at the south end of the parking lot. Follow the path marked on Figure 3.

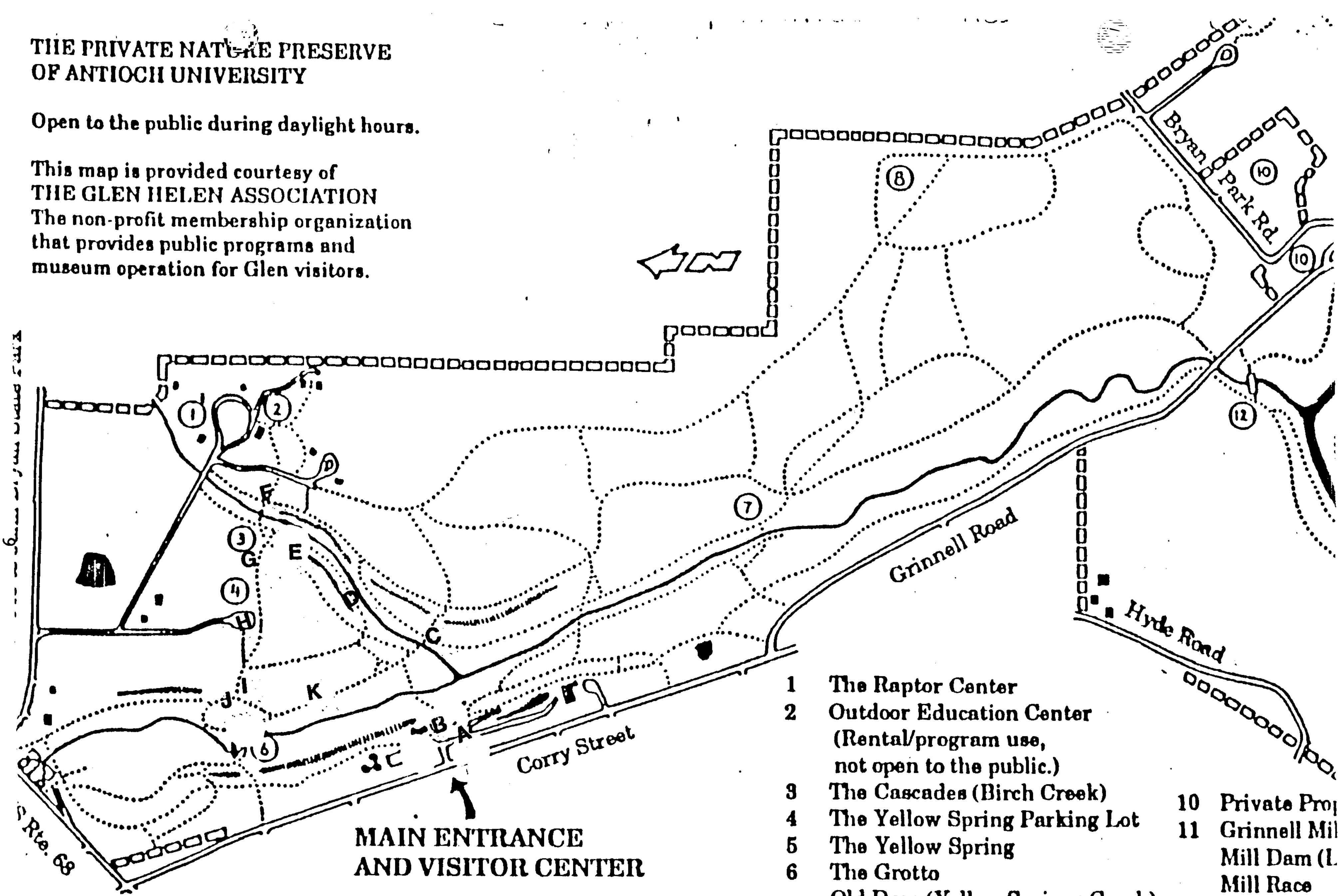
A) This glacial erratic is probably a porphyrite granite.

B) As you proceed down the steps into the valley you will be going across the Cedarville Dolomite. Please note the massive bedding and vugular character of this unit. The steps are made of Cedarville Dolomite. On some of the treads there are Partamerous Brachiopods.

THE PRIVATE NATURE PRESERVE
OF ANTIOCH UNIVERSITY

Open to the public during daylight hours.

This map is provided courtesy of
THE GLEN HELEN ASSOCIATION
The non-profit membership organization
that provides public programs and
museum operation for Glen visitors.



Glen Helen Building: Open 8:00-12 & 1-4:30 M-F
Trailside Museum: Open 10-12 & 1-5:30 Tu-F
12-530 Sat. & Sun.
▭▭ Glen Helen Boundary

1 The Raptor Center
2 Outdoor Education Center
(Rental/program use,
not open to the public.)
3 The Cascades (Birch Creek)
4 The Yellow Spring Parking Lot
5 The Yellow Spring
6 The Grotto
Old Dam (Yellow Springs Creek)
7 The Swinging Bridge (Y.S. Creek)
8 The Pine Forest
9 John Bryan State Park
to Clifton Gorge 2.5 mi.
10 Private Prop
11 Grinnell Mil
Mill Dam (I.
Mill Race
Mill Parkin
12 Covered Bri
13 To Southern
Cliff L

figure 3

C) At this site, the Osgood Shale and Laurel Dolomite are exposed. The Osgood is a calcareous shale that weathers rapidly. It is identified by the light gray clay saprolite. This unit cannot be differentiated from the Massie Shale unless seen in stratigraphic sequence. The carbonate unit exposed above the Osgood Shale is the Laural Dolomite. This unit is similar to the Euphemia and Cedarville Dolomite but is not as vuggy.

D) This is an interesting place in that travertine has cemented debris to produce a small waterfall.

E) The "Blue Hole" at this site is a plunge pool. The lip of the waterfall is composed of the Euphemia Dolomite. Erosion of the Massie Shale beneath the Euphemia produces the overhanging lip of the falls. Please note the travertine accumulation on the lip. Carbonate precipitation occurs here during the summer months when the flow is low and the water is warm. Solution occurs during the winter. Obviously there is more precipitation than solution. The trail at this location goes under an overhang where the carbonate units change from a medium bedded unit to a thick bedded unit. This is the contact between the Springfield and the Cedarville Dolomite. Please note the weathered Springfield is lighter gray than the Cedarville.

F) The lip of this waterfall is the Cedarville Dolomite. Note the backwasting of the Springfield Dolomite by this plung pool and again precipitation of Travertine on the lip. Along the side of the stream just up stream from the bridge are remnants of pot holes. Note their size and consider the volume and flow of water necessary to form a pot hole of this size.

G) Another erratic - this one is a quartzite. We are now on ground moraine and will continue to be until we reach the "Yellow" spring.

H) Another erratic - this one is banded Gneiss

I) Another erratic - this one is granite.

J) The town of Yellow Springs gets its name from this spring in the Cedarville Dolomite. The spring has a flow rate of 68 to 80 gallons per minute. The water carries iron in solution that is believed to originate from pyrite. An analysis of the spring water by Norris, Cross, and Goldthwait (1950) gave the following results in parts per million:

SiO_2	24.0	Na,K	6.9
Fe	1.4	HCO_3	406.0
Ca	89.0	SO_4	16.0
Mg	37.0	NO_3	0.1
Cl	2.5		

It is possible that the spring originates along a joint or fault. Natural (by vegetation) and now artificial damming of the spring provides a setting in which algae (blue-green and green) and mosses assist in the biochemical and incrustation and precipitation of the travertine (Scholle and others, 1983). At one time the spring supplied all the water for nearby Antioch College.

A travertine mound has been deposited by the spring (due to its porous nature it may be considered a tufa). The mound is 150 meters long by 23 meters high. The travertine has a composition of about

85% $CaCO_3$, 6% Fe_2O_3, and 9% organic matter (Bernhagen and others, 1960). Impressions of leaves and molds of stems and twigs and other vegetation that have been coated by the deposit can be seen.

Professor A.C. Swinnerton of Antioch College in 1925 calculated a maximum age of between 20,000 to 30,000 years for the deposit based on its rate of deposition (Stout, 1940). Swinnerton suggested that the mound had accumulated along the valley side since the last glaciation. Before the advent of Carbon-14 dating, this method gave a date for the retreat of ice from Southwest Ohio which is not too far from recent estimates of 17,000 years.

The Glen Helen area was a tourist attraction in the second half of the nineteenth century. This was due to the scenic beauty of the area, the "Yellow" spring which was believed to contain magical healing powers, and the proximity of the railroad. As many as 18 trainloads of visitors would arrive on Sundays with perhaps up to 5,000 people in the Glen (Leuba, 1978). A pool was built by the spring for people to take cleansing baths. A small dam was constructed in the valley of Yellow Springs Creek to provide tourists with a place to boat and swim. The visitors could stay at a hotel called Neff House which was possibly destroyed by fire in 1870 (Leuba, 1978). A rebuilt Neff House was torn down in 1892 (Leuba, 1978). By the end of the nineteenth century the popularity of the Glen had begun to decline. The lake silted up during the first half of the twentieth century and the dam had fallen into disrepair by the 1950's so that the lake has now disappeared (Leuba, 1978).

The problem being addressed at the Spring by Mike Evers' thesis is desribed in the following proposal.

THESIS PROPOSAL
THE HYDROGEOLOGY AND HYDROGEOCHEMISTRY
OF THE YELLOW SPRING,
MIAMI TOWNSHIP, GREENE COUNTY, OHIO
Submitted by Michael Evers

STATEMENT OF PROBLEM

The Yellow Spring, located in the Glen Helen Nature Preserve (Sec. 14, R.8 T.3) is characterized by several unique geologic and geochemical factors including:

1. Discharge from the Spring contains a significant amount of dissolved iron which oxidizes upon contact with the atmosphere, causing a distinct precipitate (hence the name Yellow Spring). Other springs in the area display a minor amount of iron staining, but not to the degree of the Yellow Spring.

2. Discharge from the Spring is historically constant and significantly higher than other springs located in the immediate area.

3. It has been hypothesized that the location of the spring is due to fractures in the Cedarville Dolomite.

SOLUTIONS TO THE PROBLEM

1. It is suspected that iron is introduced into the system when recharge water is in contact with the till that overlies the Cedarville upgradient from the point of discharge. By characterizing the geochemistry of the spring, I hope to describe the mechanism of iron introduction.

2. By defining the probable area of recharge, and characterizing spring hydraulics, the reasons for the historically constant discharge may become apparent.

3. Geochemical analysis of the spring discharge, coupled with geophysical data should characterize the Spring flow system as either diffuse flow or conduit flow (fracture controlled).

METHOD OF STUDY

1. Characterization of Spring water type through periodic analysis for major ions, pH, temperature, conductivity, redox potential. etc. Analysis will include at least the following major ions: SiO_2, total Fe, Ca^{+2}, Mg^{+2}, Cl^-, Na^+, K^+, HCO_3, $SO_4^=$, and NO_3^-. In conjunction with chemical analysis of Spring water, water from wells in the probable recharge area will be characterized. Chemical evolution along the groundwater flowpath will be characterized with computer simulation.

2. Study of deuterium and ^{18}O to aid in the determination of the recharge area and, if applicable, to characterize seasonal variations in recharge.

3. Study of discharge/precipitation relationships. Discharge from the Spring will be measured with a V-notch weir and local precipitation will be measured in order to investigate spring response to storm events.

4. An azimuthal resistivity and/or self potential survey will be conducted in the immediate area of the spring. Information from this survey, coupled with study items 1 and 2 should give additional information on the bedrock control of the spring.

K) Pompey's Pillar - this is a hoodoo. It is an example of differential erosion of the Cedarville (on top) the Springfield (in the middle) and the Euphemia (on the bottom). Some guides say this is moving toward the streams by frost action. I think this is unlikely and the unit is an erosional remnant. However, you should note the large lilted blocks of the Cedarville Dolomite that are obviously in transit to the stream via mass wasting.

This is the end of the trip. Return to the parking lot. I hope you had a good day and have a safe trip home.

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FRACTURE-CONTROLLED EROSIONAL PROCESSES AND AQUIFERS AT THE NIAGARAN GROUP ESCARPMENT, SOUTHWESTERN OHIO

part of handout/guide for 1990 Ohio
Academy of Science Section
of Geology field trip through
Glen Helen

SUMMARY

Research described in this report indicated that bedrock aquifers in the Niagara Group carbonates of Southwestern Ohio are fracture controlled. The fractures concentrate groundwater flow and influence karst and erosional processes along the Silurian escarpment in the headwaters of the Little Miami River.

Traces of fractures in the Silurian carbonate rocks are visible on air photographs in areas where glacial deposits of moderate thickness cover the bedrock.

The new data described in this report are important for understanding groundwater flow in carbonate bedrock reservoirs. The fracture systems that control groundwater flow are mappable in spite of the cover of Quaternary glacial deposits. These fractures should be taken into account in the hydrogeological assessment of hazardous waste sites and spills that occur in areas having bedrock at shallow depth.

Mapping of fracture systems should be incorporated in the procedures for evaluation of susceptibility to contamination under the DRASTIC mapping program.

Raphael Unrug
Project Director

Chapter 4

Results: Field Investigation

4.1 General Morphology

Geomorphological mapping and joint studies in the Clifton and Yellow Springs gorge area reveal interesting distributions and possible relationships of various geologic features and processes.

The gorges are formed by headward erosional processes at the Niagaran Escarpment, including both downcutting by streams and fracture controlled groundwater flow. The Clifton Gorge is formed by the Little Miami River, and trends west-southwest from the head of the gorge near Clifton (579 085) to its confluence with the Yellow Springs Gorge about 5 kilometers away (536 076) where the valley widens (figure 9). The Yellow Springs Gorge trends south- southeast from its head near Yellow Springs (530 100) to the confluence of the two gorges at (536 076). These gorges form a necessary pathway for drainage flowing from the north and east atop the Niagara Group to the wide, low valley system to the southwest that in many places is formed in coincidence with deep buried valleys.

Clifton Gorge varies dramatically in character from its head, where it is a steep walled, narrow bedrock gorge on the order of 5-15 meters deep and 10-30 meters wide, to its mouth at the confluence of the gorges where the bedrock is obscured by till, and the valley is about 500-1000 meters wide and 30-35 meters deep. From a map view, the gorge forms about nine relatively straight segments that meet one another at angular junctions. These segments become progressively wider in the downstream direction.

The Yellow Springs Gorge is, on the other hand, a markedly straight feature trending N10W. The morphology of this gorge is less variable than the Clifton Gorge. Although the breadth of the gap in the uppermost cap rock widens progressively from 300 meters at the head of the gorge to 600-700 meters at the mouth, the steep walled gorge cuts down through the Brassfield Limestone, maintaining a 200-300 meter width for the entire length of the gorge. Furthermore, the flat valley bottom maintains a width of 75-100 meters throughout the gorge, as opposed to the bottom of the Clifton Gorge that progressively widens.

4.2 Nature of the Bedrock

The massive Cedarville Dolomite and the underlying Springfield Limestone forming the Niagaran Escarpment are exposed at the margins of the gorges in much of the area at an elevation of approximately 290 meters. Till obscures about 5 kilometers of this escarpment northeast of the confluence of the gorges, along the south part of the east side of the Yellow Springs Gorge and the western part of the north side of the Clifton Gorge. The nature of the outcrop of the Niagara Group varies along with the general morphology of the gorges. In the narrow headward areas, the outcrop forms a nearly vertical and continuous cliff, whereas in the wider parts of the gorge the outcrop is more typically observed as low, discontinuous outcrops of the uppermost few meters of the carbonate sequence. Thin bedding is characteristic of the Springfield Formation, and lenses of thin bedding exist within the Cedarville Formation at some localities. The Niagara Group outcrop as a whole appears less massive in the Yellow Springs Gorge (53 09), where the exposed thickness of the massive Cedarville Formation is 2-3 meters thick, as opposed to 6-10 meters at Clifton Gorge (figures 15, 16, 17).

Another point of interest is that everywhere the Niagara Group is exposed, the upper 1-3 meters of the massive dolomite is riddled with solution holes (figure 18). These solution holes range in size from less than a centimeter to many tens of centimeters. Most appear isolated and unconnected to others, while some form deep, narrow cavities in the rock, seemingly a group of connected solution holes. This highly porous layer of rock visibly ends abruptly downward at most localities. This solutioned layer may be a result of near surface weathering of the bedrock by groundwater, its depth of penetration possibly controlled by stratigraphic inhomogeneities. It is also possible that the vugs are an entirely stratigraphic feature formed at depth, but since the more porous layer is at the top of the carbonate outcrop regardless of what stratigraphic interval is exposed it seems more likely to be a weathered zone. Legrand and Stringfield (1973) note that fractured carbonate rocks with solution enlarged fractures typically exhibit rapidly decreasing overall permeability with depth below the water table.

At many points in the gorge, undercuts are formed beneath the massive Cedarville Dolomite by the weathering of the less resistant Springfield Formation. These undercuts appear to be intensified in association with springs and joints.

The Brassfield Limestone is visible in many outcrops, and forms prominent benches at an elevation of about 275 meters. The outcrops of this formation are less prominent than those formed by the Cedarville and Springfield formations, and are not as continuous. Like the Cedarville Dolomite, upper parts of this formation are also vuggy in places, particularly at the margins of the prominent benches formed near (548 075).

Outcrops of the Osgood Shale are rare. This formation is visible east of the John Bryan State Park campgrounds, at points where the sides of the gorge have been eroded deeply (553 077), (558 079), (555 083). Another good exposure is formed about 300 meters south of the Yellow Spring, at grid (553 096), in the south facing embankment at the mouth of Birch Creek. Within this tan to grey, calcareous shale are thin limestone layers, generally more abundant near the top of the formation.

4.3 Springs

Springs occur throughout the gorges, both at the base of the Niagara Group carbonates and at the base of the Brassfield Limestone. In both cases, groundwater is diverted laterally by shale sequences that preclude downward percolation of groundwater.

The springs range from wet spots at the base of the cliffs to formidable streams of water (perhaps 25-50 cubic meters per day) issuing out of limestone, talus or debris. The most typical form is a circular patch of upwelling water about 3 meters in diameter, littered with pebbles and cobbles of carbonate nodules deposited by the spring water (figure 18).

Travertine mounds formed by the spring deposits have accumulated in association with most large springs. These vary from thin caps of spring deposits overlying shale, talus, or bedrock, extending perhaps 5-10 meters from a spring, to impressive domes several meters thick and up to 200 meters in diameter laterally. Figure 19 depicts a travertine mound on which the spring shown in figure 18 is located (551 078). The travertine mounds upon which larger springs occur have one or more streams running down the dome-like surface. These streams are observed to be placed randomly about, occurring in the center, sides , or intermediate positions on the travertine mound. This can be likened to the behavior of stream migration on alluvial fans.

Small debris fans exist below some of the travertine mounds where the streams formed by the springs reach the flood plain of the river below. These debris fans are formed of mixed carbonate spring deposits, organic material, and redeposited till.

The Yellow Spring, at grid (530 100), is the largest spring in the gorge area (figure 20). According to Goldthwait (1950), flow measurements by Bennison (1941) range from 327 to 436 cubic meters per day. This spring is not only atypical in its size, but in several other aspects as well. Deposits formed by this spring are rust red, reflecting high iron content and deposition of iron oxides (as reported by Goldthwait, 1950). No other spring observed in the entire gorge area has this distinct red appearance. Deposits at other springs are characteristically light tan carbonate deposits. Moreover, the Yellow Spring is anomalous in that it does not issue from the base of the carbonate group, but rather out of bedding planes in the rock high on a cliff that has been buried by spring deposits. It actually appears that this large spring is depositing so much material that its accumulation has driven the position of the spring upward to its current location high on the cliff.

The position of springs does not appear to be random. Individual springs and groups of springs tend to occur across from one another on opposite sides of the gorges. Springs occur both at or near points where storm gulleys exist above the cliffs in the glacial debris as well as in areas where no gulleys are present. Plate 1 shows positions of travertine deposits and springs. Note the bands of spring deposits about one kilometer wide on both the north and south sides of the Clifton Gorge near the middle of the plate, and a similar band of springs along the west side of the Yellow Springs Gorge across from Birch Creek. Also note the isolated pair of travertine piles about 500 meters west of the corner of the Clifton Gorge at Twin Springs.

4.4 Joints

Detailed examination of jointing in the Cedarville Dolomite reveals interesting relationships and patterns. Measurements of 556 large joints imply that there are at least four primary trends of jointing. Figure 21 is a rose diagram displaying these measurements. As expected, there is some degree of scatter among the individual joints that tend to trend in some general direction. In this discussion, it will be useful to refer to these trends by their approximate average orientations. The four trends indicated by the rose plot are N45W, N20E, N42E, and N70E. These trends are referred to as joint sets or groups of joints.

There is a possibility that a fifth trend may exist in the direction of N10-15W. Evidence suggesting this includes the straight, linear trend of the Yellow Springs Gorge, as well as patterns visible on both aerial photographs and topographic maps immediately to the west of the field map area. It seems more likely, however, that these features are a result of glacial processes entirely unrelated to fractures, as will be discussed later.

All of the joint sets occur as nearly vertical planes in the massive Cedarville Dolomite. Early in the study, it was found that the time consuming activity of measuring the vertical dip of every joint would not yield a great deal of valuable information, partly because uncertainties due to the fact that slumping and other movements at the cliffs are greater than the observed deviation of the joints from a vertical position. Early measurements suggest that joints dip within five degrees from vertical in general, with no apparent preference as to which way the joint may deviate from vertical within any joint set direction.

Joints trending in different directions display several distinguishing characteristics. Joints trending N45W are relatively widely spaced, prominent fractures that are either isolated or in groups of 2-5 fractures spaced about one meter apart.

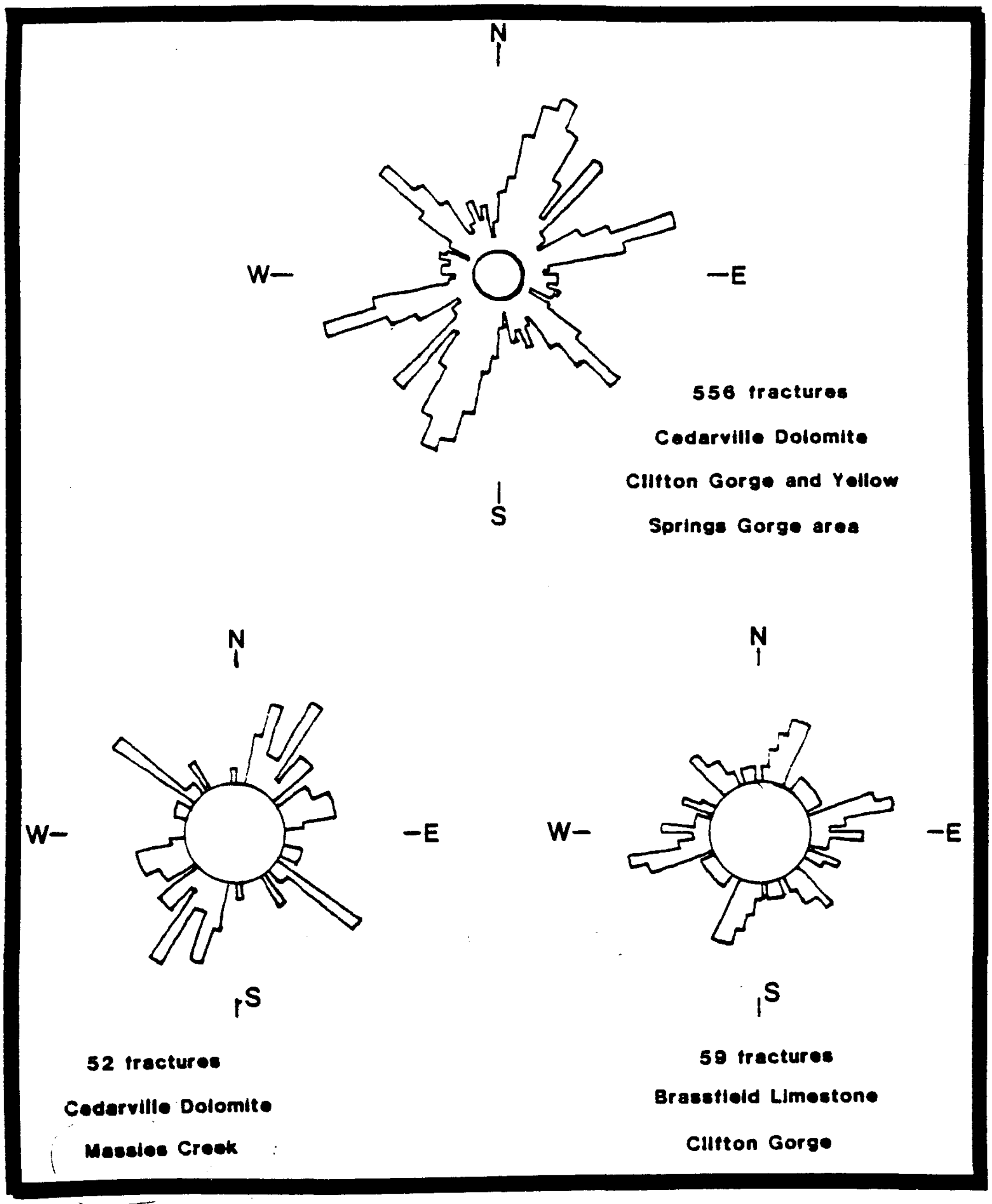

Figure 21. Rose Plots. These rose diagrams show the prominent trends of nearly vertical fractures in bedrock. Note the prominent trends are persistent in all three plots. The prominent trends at the Clifton Gorge and Yellow Springs Gorge area average N45W, N20E, N42E, and N70E.

In a given area, their trends deviate very slightly, within a few degrees of one another. These joints are nearly everywhere vertically continuous through the massive dolomite and are observed in many localities as open cracks penetrating laterally into the cliff. The sides of these large cracks are riddled with solution holes, indicating deep weathering caused by enhanced groundwater flow over long periods of time (figure 22). Joints of other trends abut these extensive, prominent N45W joints, suggesting an earlier formation of this group relative to other groups of joints.

Joints trending N42E are similar in description to those trending N45W, but seem to be less abundant. Like the N45W joints, the N42E joints exhibit a strong preferential orientation with little deviation, are vertically penetrating, and other joints abut them laterally. Even though this group does not appear as an obviously prominent peak on the cumulative joint rose diagram, the dominating characteristics of this joint set was observed in the field.

Joints trending N20E display characteristics distinctly different than the N45W and N42E trending joints. These joints typically penetrate the Cedarville Dolomite vertically for a distance of a few meters, then being offset by bedding planes or horizontal joints to an alternate position, as a whole forming horizontally displaced vertical planes at different levels in the cliff (figure 23). As indicated by the rose plot of joints (figure 21), this joint set exhibits the greatest degree of scatter in orientation of individual joints. The discontinuous nature of the individual joints in this set are evident both vertically, as the joint planes are disrupted by horizontal bedding features, and laterally as these joints tend to abut joints of other directions, continuing laterally as another joint at some offset position. Fracture mapping indicates that zones of more densely spaced joints in this direction may penetrate laterally for long distances even though the individual joints appear to be discontinuous.

Joints trending N70E are intermediate in nature, some exhibiting features similar to those of the N45W and N42E joints, while others appear more like those of the N20E set.

Interestingly, some of the prominent vertical fractures penetrating most of the Cedarville Dolomite do not extend upward into the vuggy layer above.

Note on Plate 1 the variance of the local rose diagrams. Much of this variance is due to the orientation of the cliff faces in each area mapped. This effect is pronounced in the rose diagrams in the Yellow Springs Gorge where N20E group joints are more abundant. This is more likely an effect of erosional processes at the cliff faces than an indication of more intense primary jointing (formed before exposure, at depth). No attempt was made to select only joints of a certain relative age. The variance of the local rose diagrams suggest a large number of joint measurements (perhaps 100 or more) should be made to get a realistic indication of prominent trends.

Joint measurements at the gorge formed by Massies Creek, about 8 kilometers south-southeast of the field study area, indicate the same trends in jointing exist there in the Cedarville Dolomite. Joint measurements at John Bryan State Park in the Brassfield Formation also reflect the same trends.

4.5 *Relation Between Springs and Joints*

Many springs are visibly located at the junction of large fractures with the cliff faces in the Cedarville Dolomite. Very obvious examples include the spring at (551 078) (figure 18) on the north side of the Clifton Gorge and the spring across the gorge to the south at (076 554) (figure 24). These two large springs are in fact located in a line trending N55W as determined from a map view, while the fractures directly visible above the springs are measured as N51W and N50W at the north and south sides, respectively. Additionally, there are two joints approximately one meter apart above both springs.

Another example is along the north side of the narrower part of the Clifton Gorge near (570 087) where a small, intermittent spring is positioned at the base of an impressive N45W group fracture exhibiting the prominent, penetrating nature of joints of this set.

Plate 1 shows the relation between springs, nearby fracture directions at some localities, and fracture traces.

Along part of the south side of the gorge, the surface drainage parallels the fractures in the bedrock, and the drainage is diverted underground forming a large spring (figure 24). Figure 25 shows the nature of the cliff at a point where the surface drainage intersects the gorge wall where large vertical fractures are not present. Here, the drainage remains at the surface and is not diverted underground.

It appears springs are controlled by fractures and their relation to the topography. The topography is likely to have a direct influence on the groundwater head distribution. The fractures act as conduits for groundwater flow. Clues to the relationship between topography, fracture traces, and springs are found by comparing Plate 1 to a topographic map (some contours are shown in the uplands portion of Plate 1). If the travertine deposits are considered evidence of significant spring activity, their locations in relation to the topography prove interesting. The positions of fracture traces (Section 5.1 and Plate 1) provide additional information.

The two travertine mounds in the vicinity of grid (562 081) are offset across the gorges at about the same angle as the fracture trace that extends south of the area, trending N20-25E. These springs are not associated with any topographic lows in the upland areas near the gorge, or with the surface drainage system. Considering the general absence of springs along the west side of the NNE trending portion of the gorge between the Twin Springs area (567 081) and the pool at (569 087) it seems possible that NNE trending fractures are capturing groundwater north of the vicinity of the two isolated travertine mounds and directing it to the spring resposible for the travertine deposits. This would prevent springs from forming along the NNE trending portion of the gorge.

Broad topograghic lows, about 1000 m wide, are located both north and south of the area of dense travertine deposits in about the middle of the map area, in the vicinity of (551 077). The deposits, however, are somewhat offset from the topographic lows. The bands of travertine deposits, about 700m long on both sides of the gorge, are offset from one another in the same direction as the prominent N45W fractures and fracture traces in the area (Plate 1)(see also figure 41). This suggests that the topographic lows may be influencing the available water supply, while fractures serve as localized subsurface flow channels finally directing the water to the gorge, which acts as a sink.

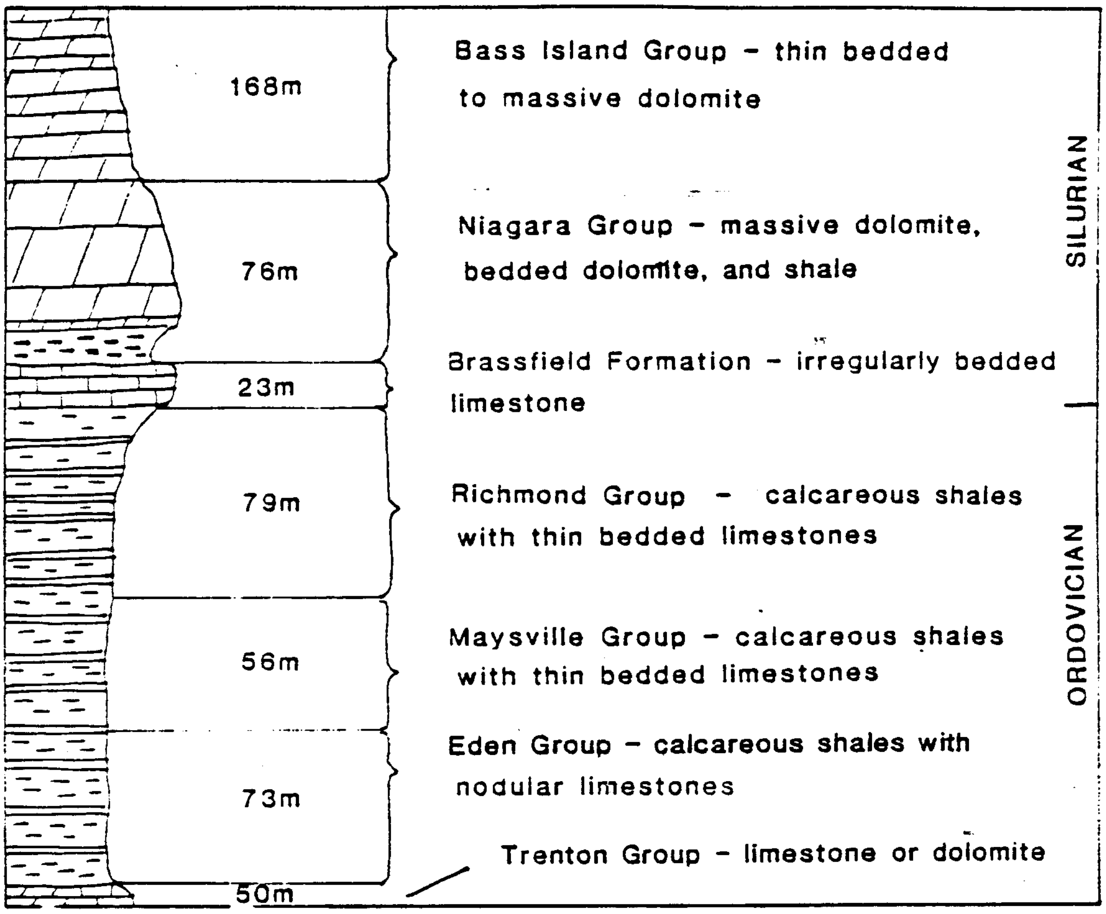

Figure 5. General Stratigraphy in Southwest Ohio. Sources: Stout et al., 1943; La Rocque and Marple, 1985.

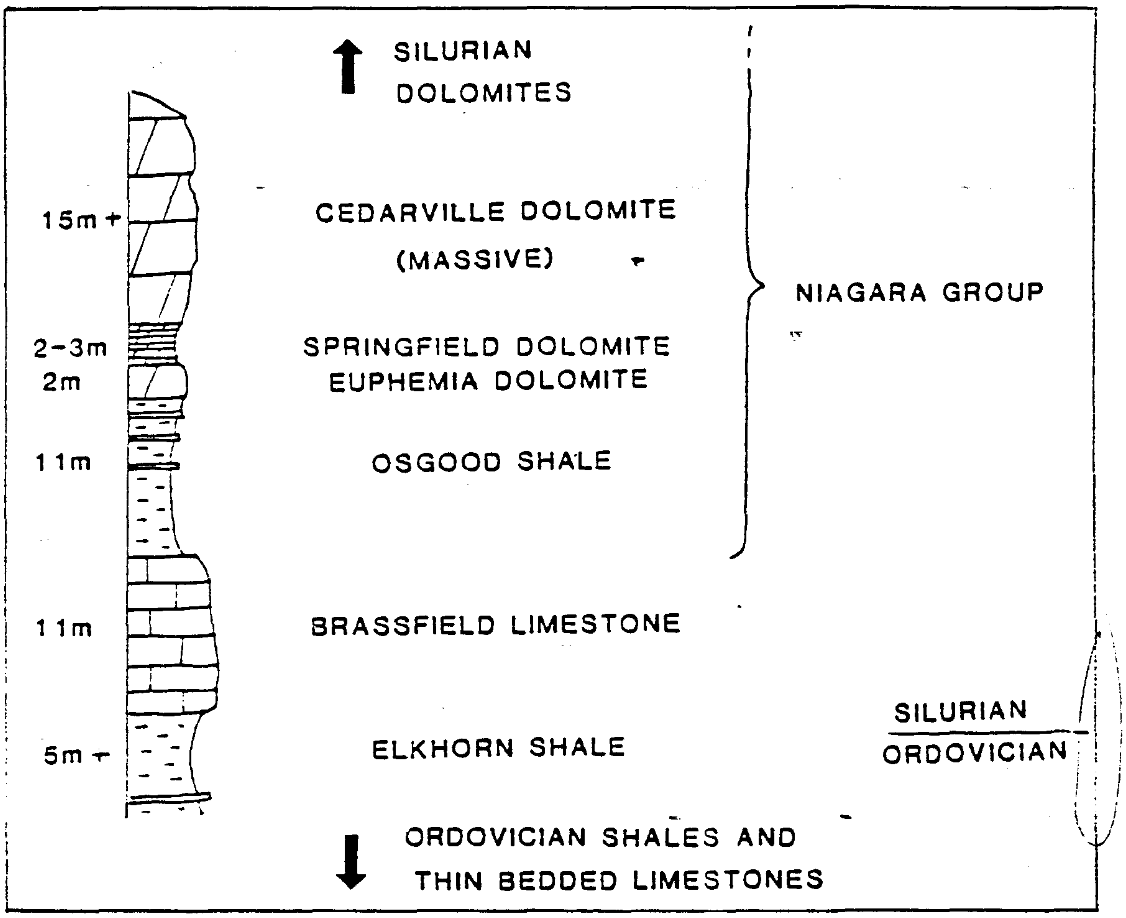

Figure 8. Stratigraphy in the Clifton Gorge Area. Source: Carmen, 1946.

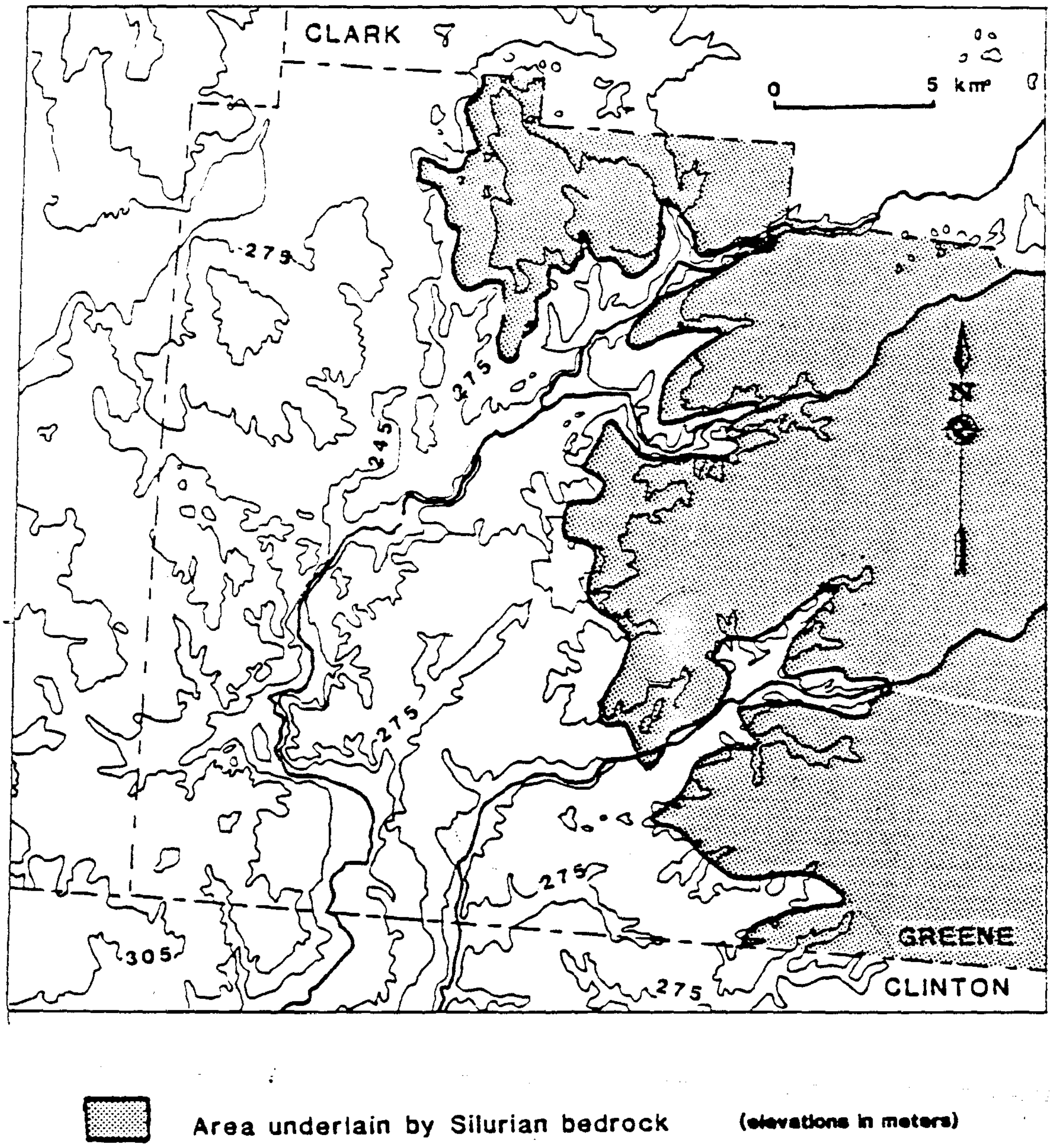

Figure 7. Position of Niagaran Escarpment in Greene County. Escarpment is formed at the Silurian-Ordovician contact. Source: Norris, 1950.

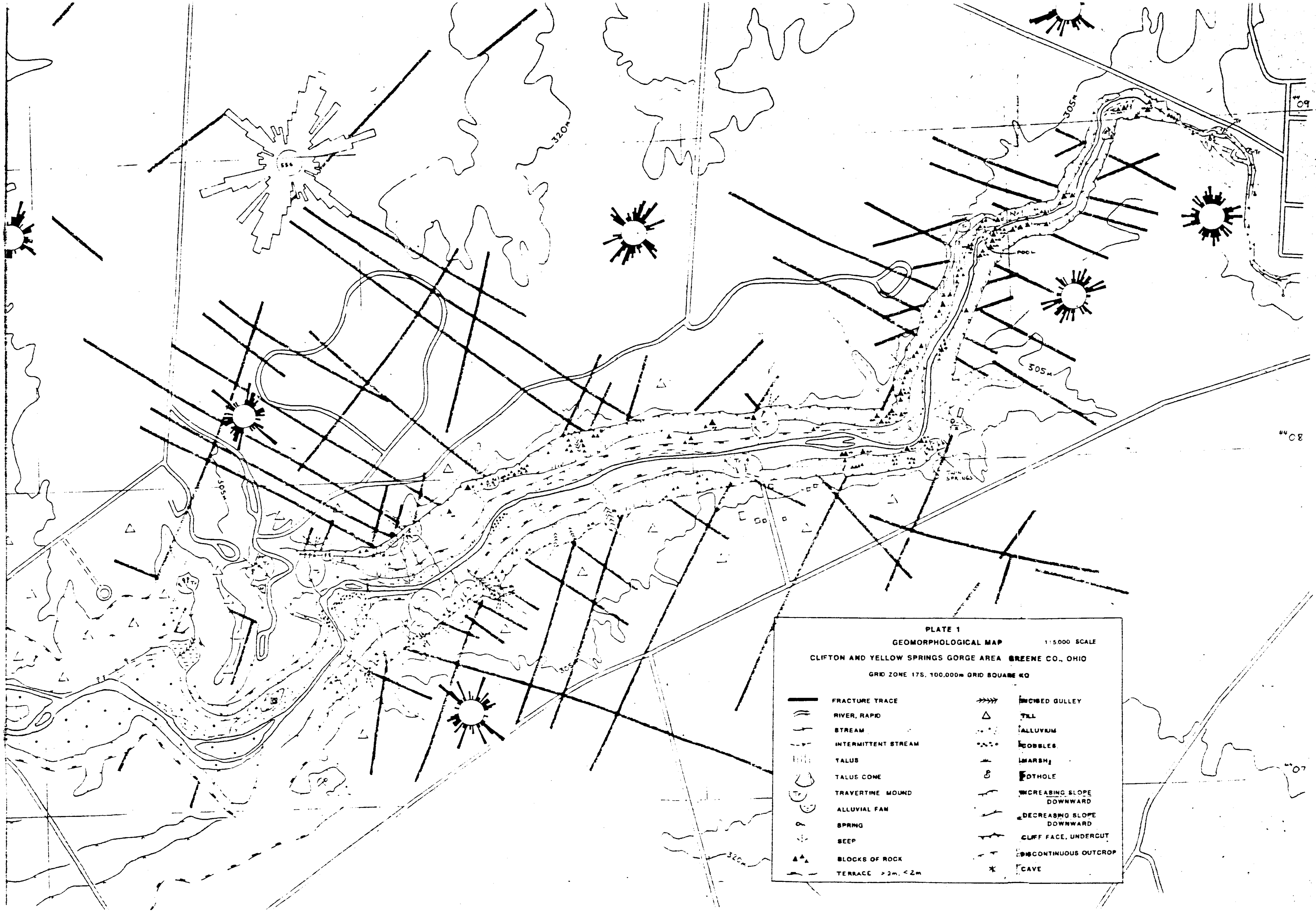
PLATE 1
GEOMORPHOLOGICAL MAP
1:5000 SCALE
CLIFTON AND YELLOW SPRINGS GORGE AREA GREENE CO., OHIO
GRID ZONE 17S, 100,000m GRID SQUARE KQ
FRACTURE TRACE
RIVER, RAPID
STREAM
INTERMITTENT STREAM
TALUS
TALUS CONE
TRAVERTINE MOUND
ALLUVIAL FAN
SPRING
SEEP
BLOCKS OF ROCK
TERRACE >2m, <2m
INCISED GULLEY
TILL
ALLUVIUM
COBBLES
MARSH
POTHOLE
INCREASING SLOPE DOWNWARD
DECREASING SLOPE DOWNWARD
CLIFF FACE, UNDERCUT
DISCONTINUOUS OUTCROP
CAVE
320m
305m
320m
305m
POOL
SPRINGS
305m
320m
09
08
07